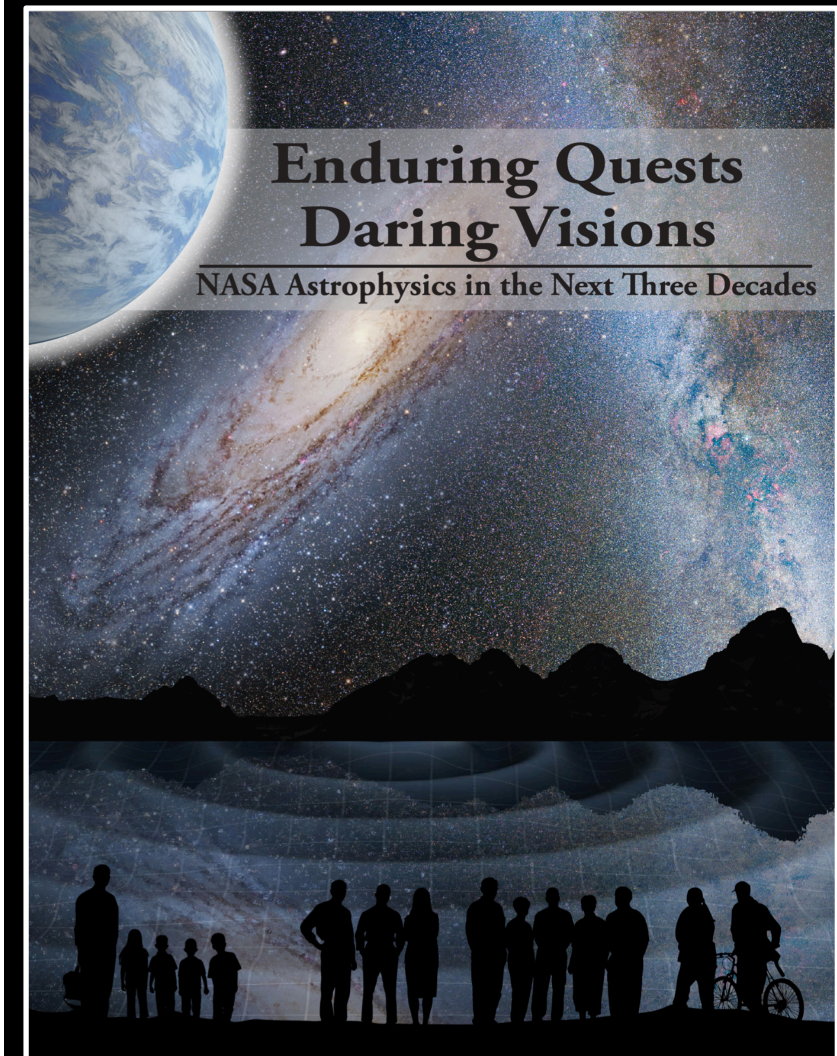
On behalf of the Roadmap team.

Enduring Quests – Daring Visions

NASA – Astrophysics Division Roadmap



Charter:

- Provide a compelling 30-year vision
- Build on Astro 2010 Decadal Survey
- Science based notional missions
- Developed by a task force of the APS
- Include community input
- Be delivered to the APS

A long-range vision document with options, possibilities, w/ visionary futures

Charter is not a mini-decadal survey, does not have recommendations or priorities, is not an implementation plan

Enduring Quests – Daring Visions

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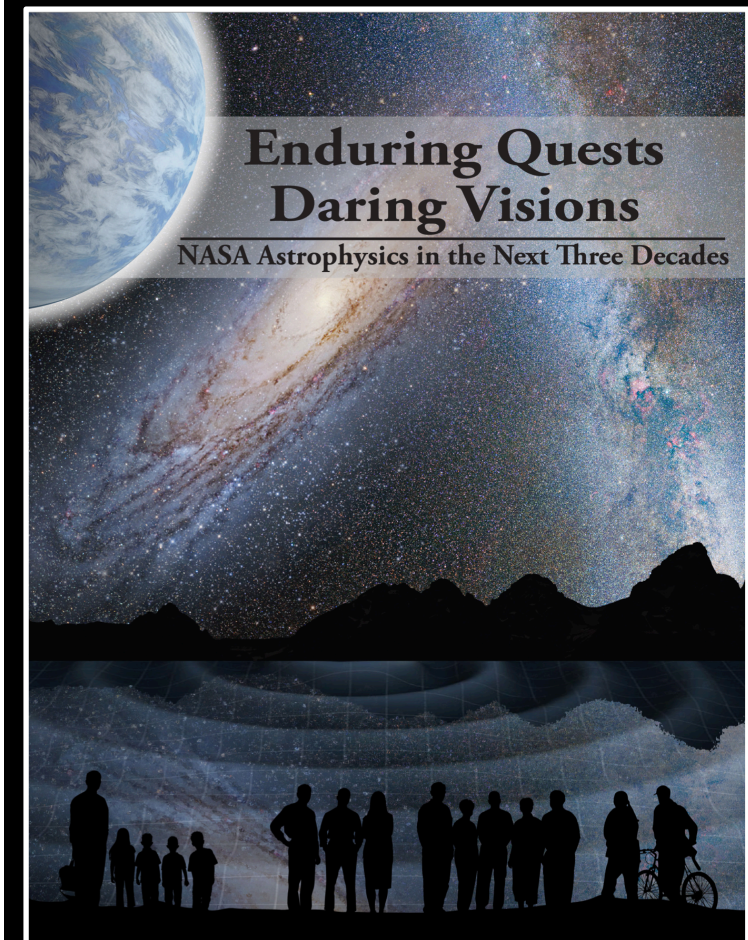

The Team

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Brad Peterson, APS Chair
Joan Centrella, APS Exec Sec

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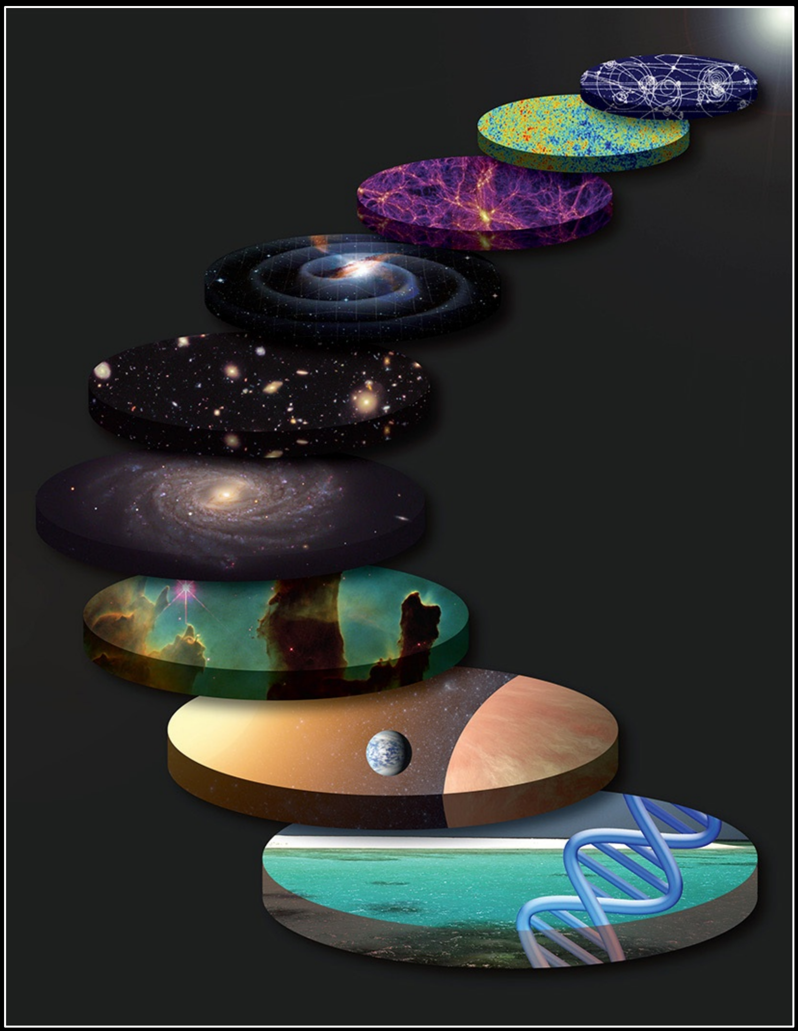


Three enduring science questions:

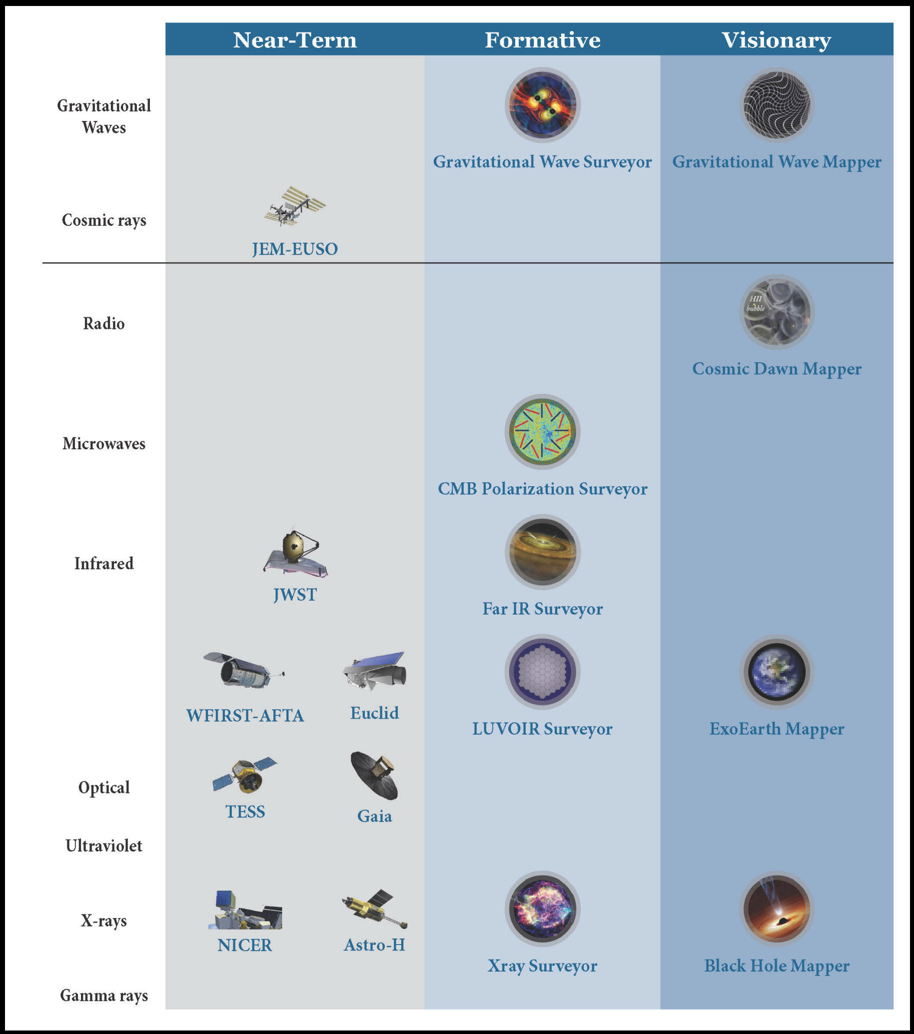
Are we alone?

How did we get here?

How does the universe work?

Enduring Quests – Daring Visions

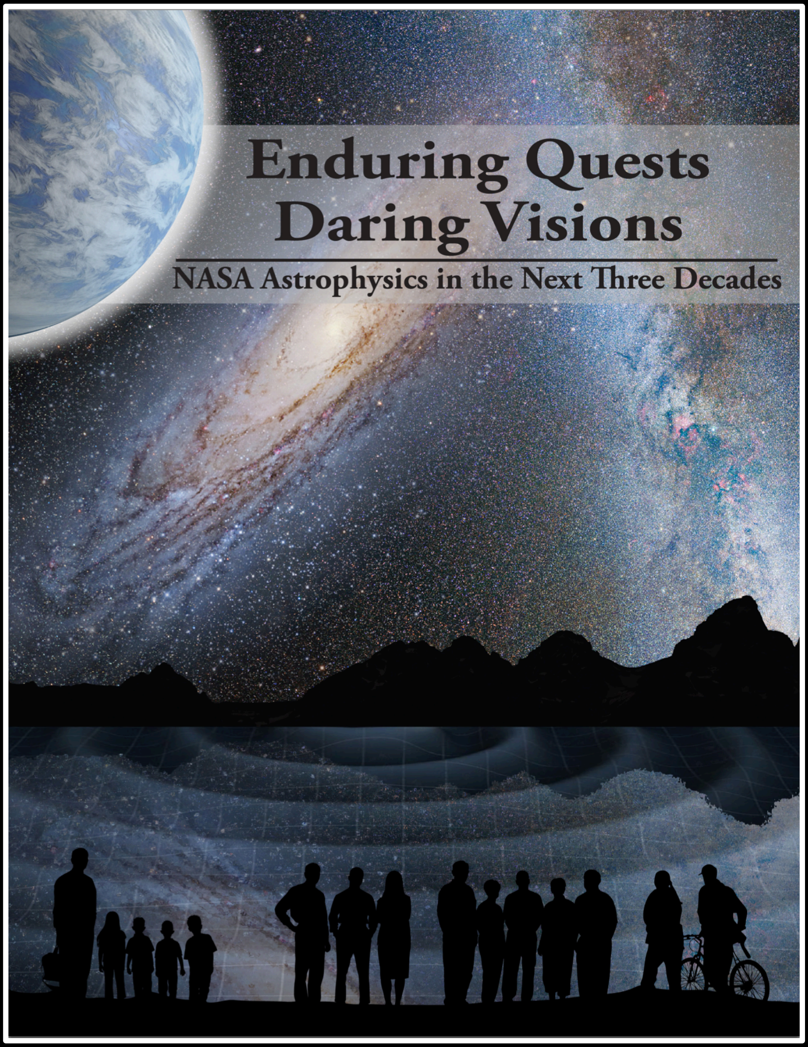
NASA – Astrophysics Division Roadmap

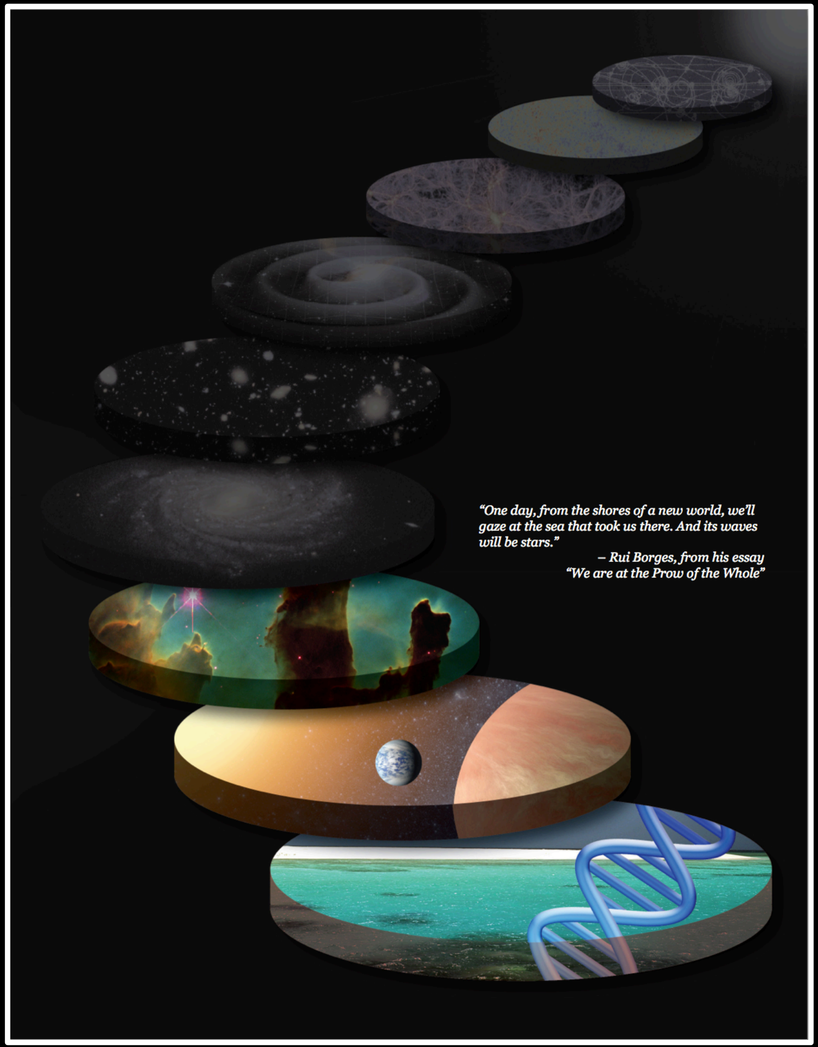


Three eras:

- Near-Term (current or planned)
- Formative (10-20 years)
  - Notional Mission Surveyors
- Visionary (20+ years)
  - Notional Mission Mappers

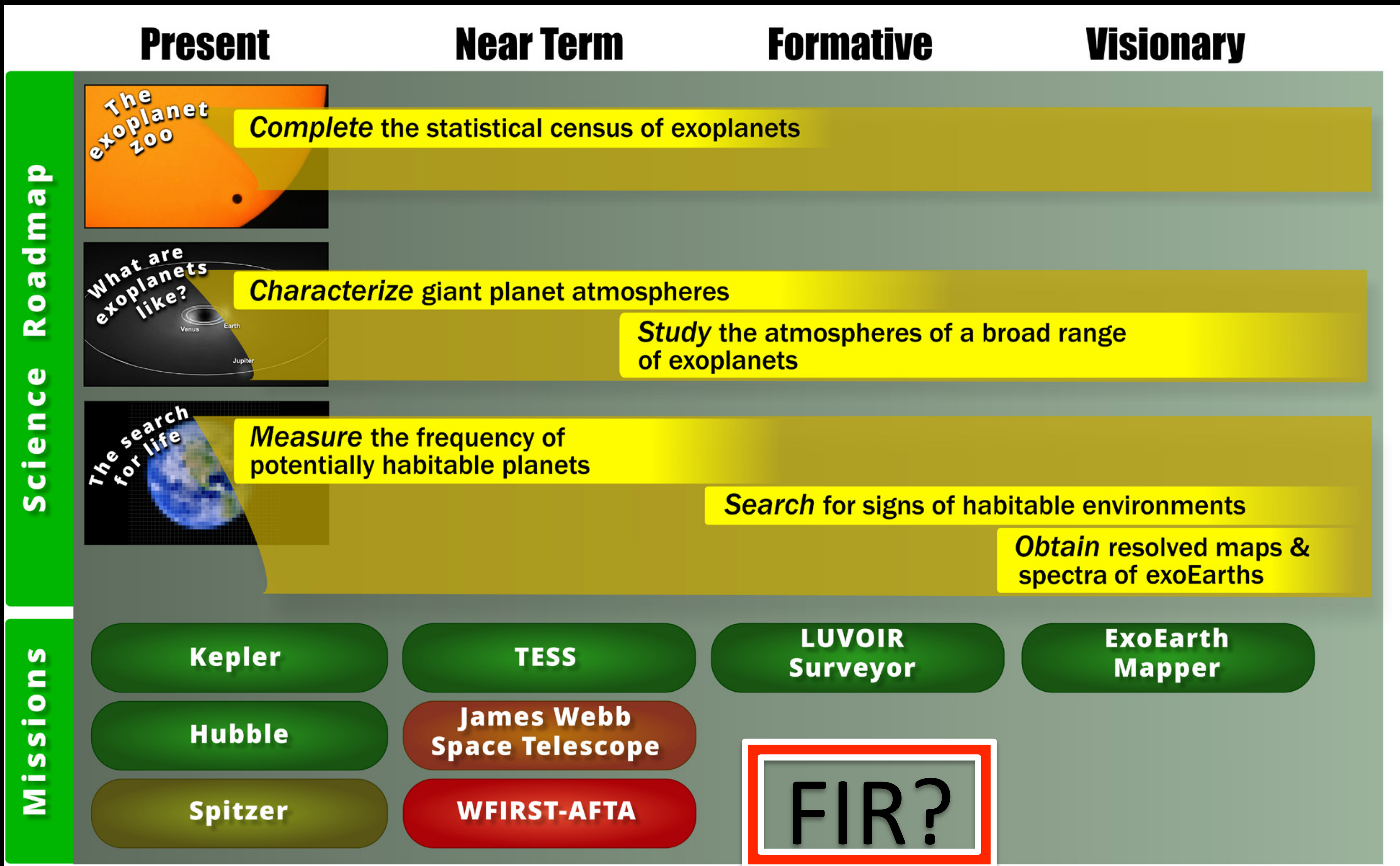
Are we Alone?





1.) The Exoplanet Zoo
2.) What are Exoplanets Like?
3.) The Search for Life

Are we Alone?



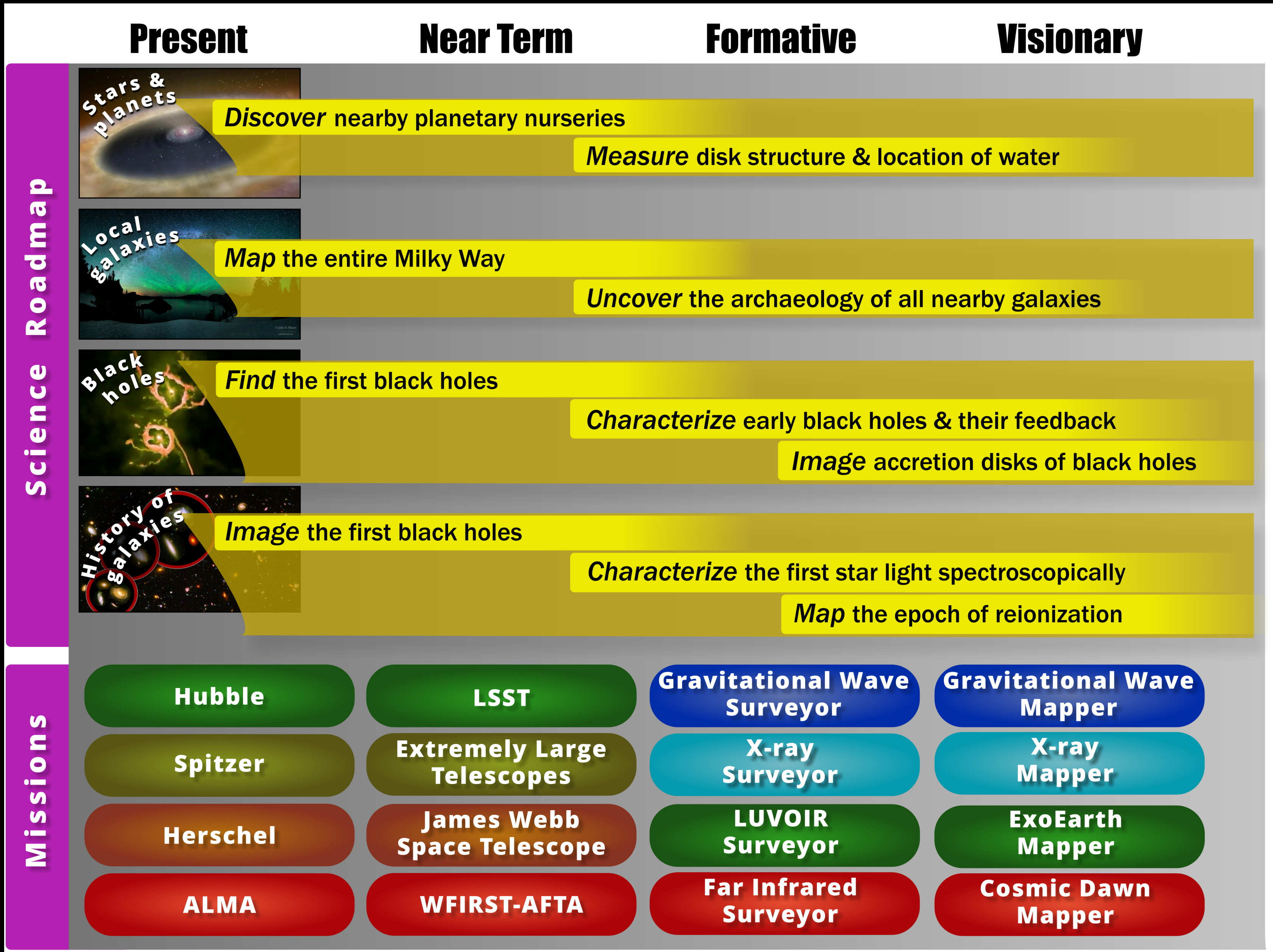
Present
Near Term
Formative
Visionary
Science Roadmap
The exoplanet zoo
Complete the statistical census of exoplanets
What are exoplanets like?
Venus
Earth
Jupiter
Characterize giant planet atmospheres
Study the atmospheres of a broad range of exoplanets
The search for life
Measure the frequency of potentially habitable planets
Search for signs of habitable environments
Obtain resolved maps & spectra of exoEarths
Missions
Kepler
TESS
LUVOIR Surveyor
ExoEarth Mapper
Hubble
James Webb Space Telescope
Spitzer
WFIRST-AFTA
FIR?

How did we get here?

Map newborn stellar and planetary systems across the Milky Way

Characterize the detailed nature of the Universe's first galaxies and chemo-dynamical growth of galaxy components over cosmic history

How Did We Get Here?



Stellar Nurseries

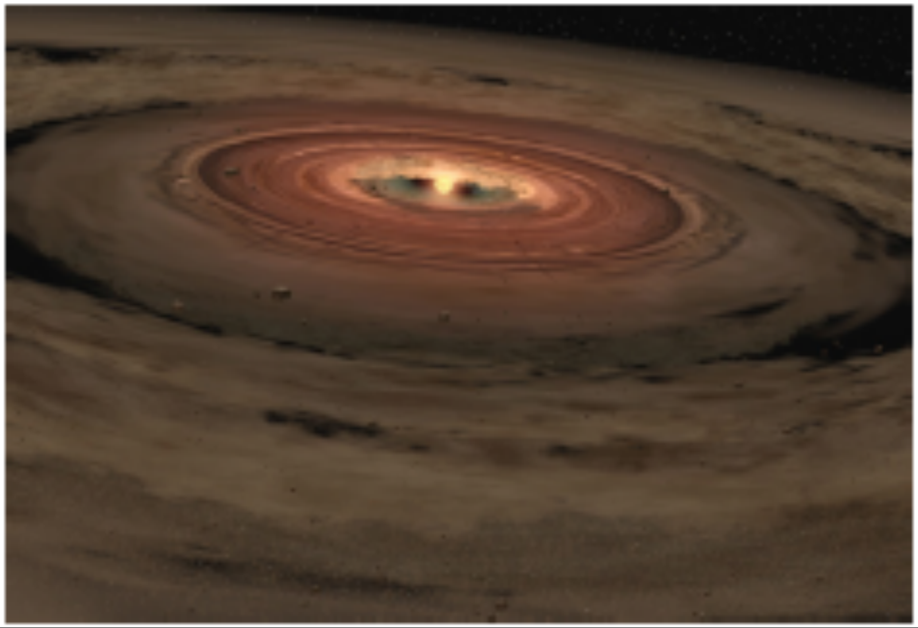
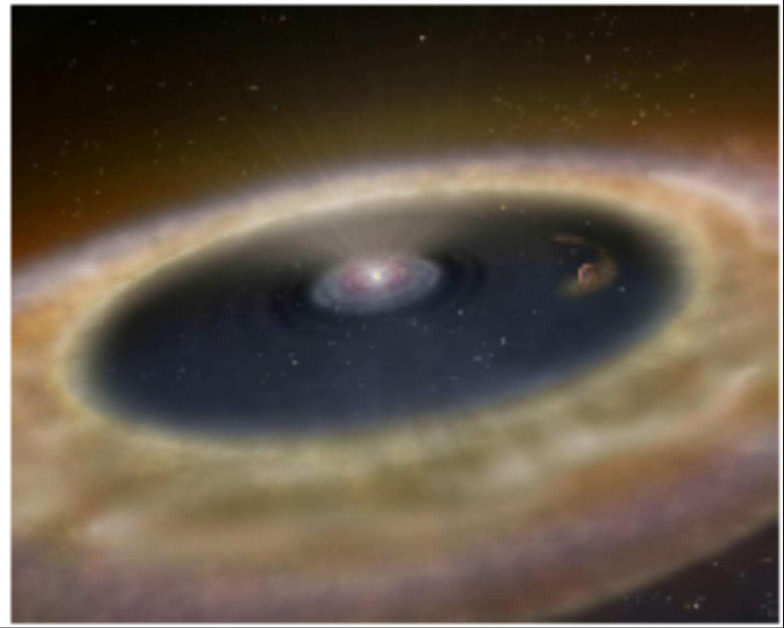



Chart 1000s of stellar nurseries

ALMA: Cold gas, dust + planets via protoplanetary disk gaps, also chemical composition of stellar nurseries.

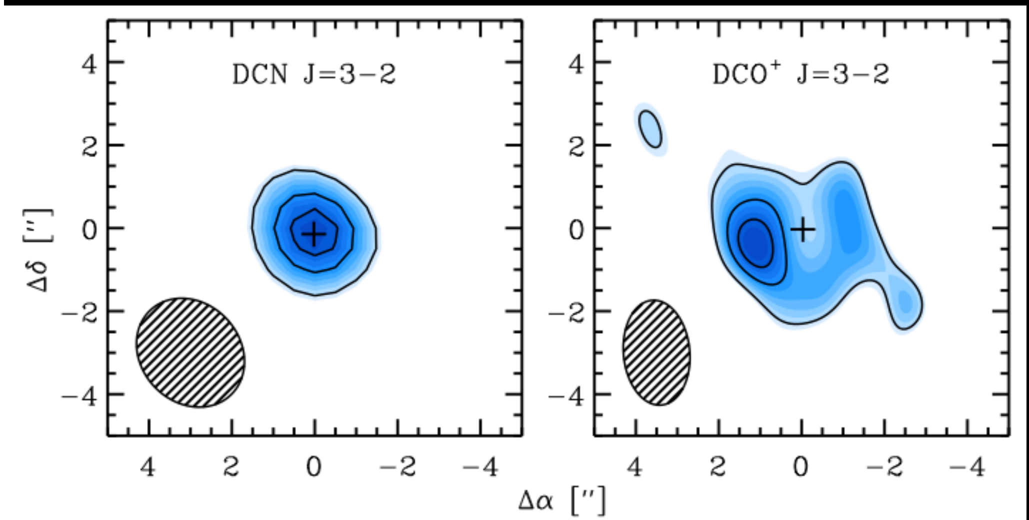
JWST / ELTs : Hotter dust / inner regions of star systems + search for rocky planets in the inner regions

Water – direct detection

We need to directly detect water in protoplanetary disks and map its locations

Tracer species (deuterated molecules) → confusing results

FIR Surveyor will map water emission for ALMA/JWST identified systems



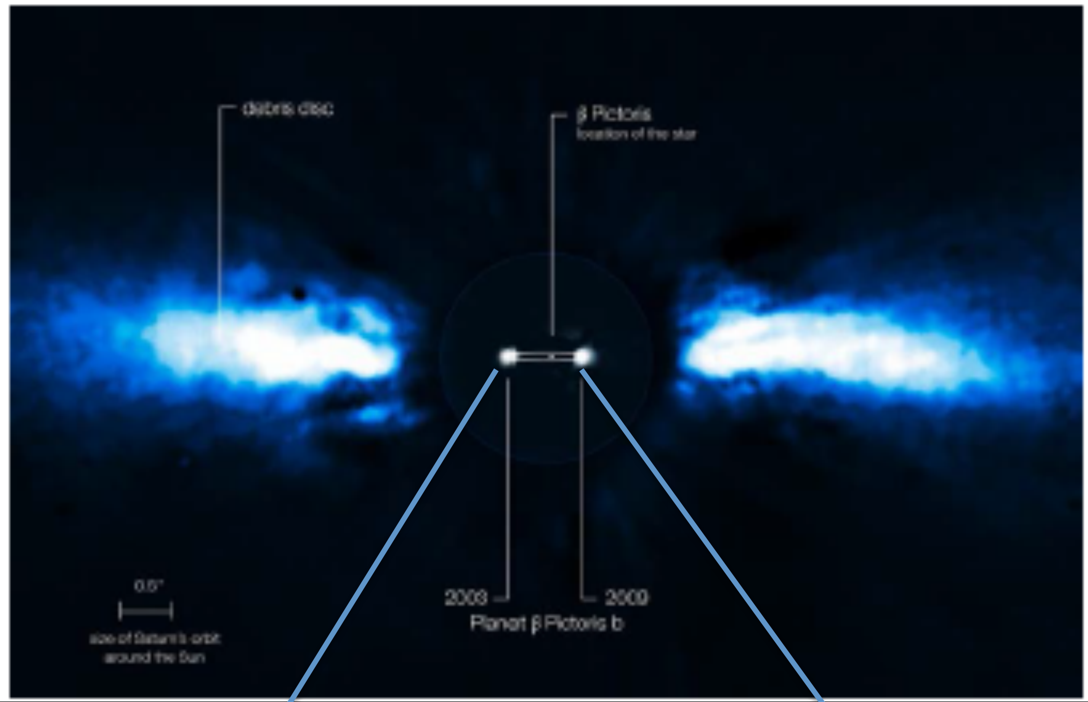
Oberg et al. 2012

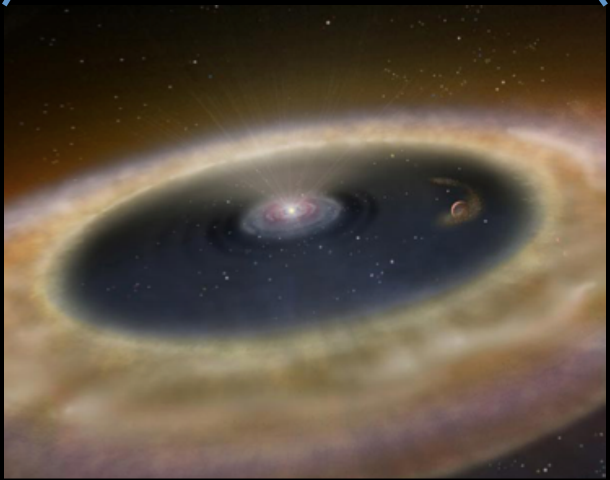
Debris Disks

Debris disks are key links between protoplanetary disks + mature star systems

Initial work with HST has probed a few systems

LUVOIR needed to map gaps and clumps in inner regions of these systems.

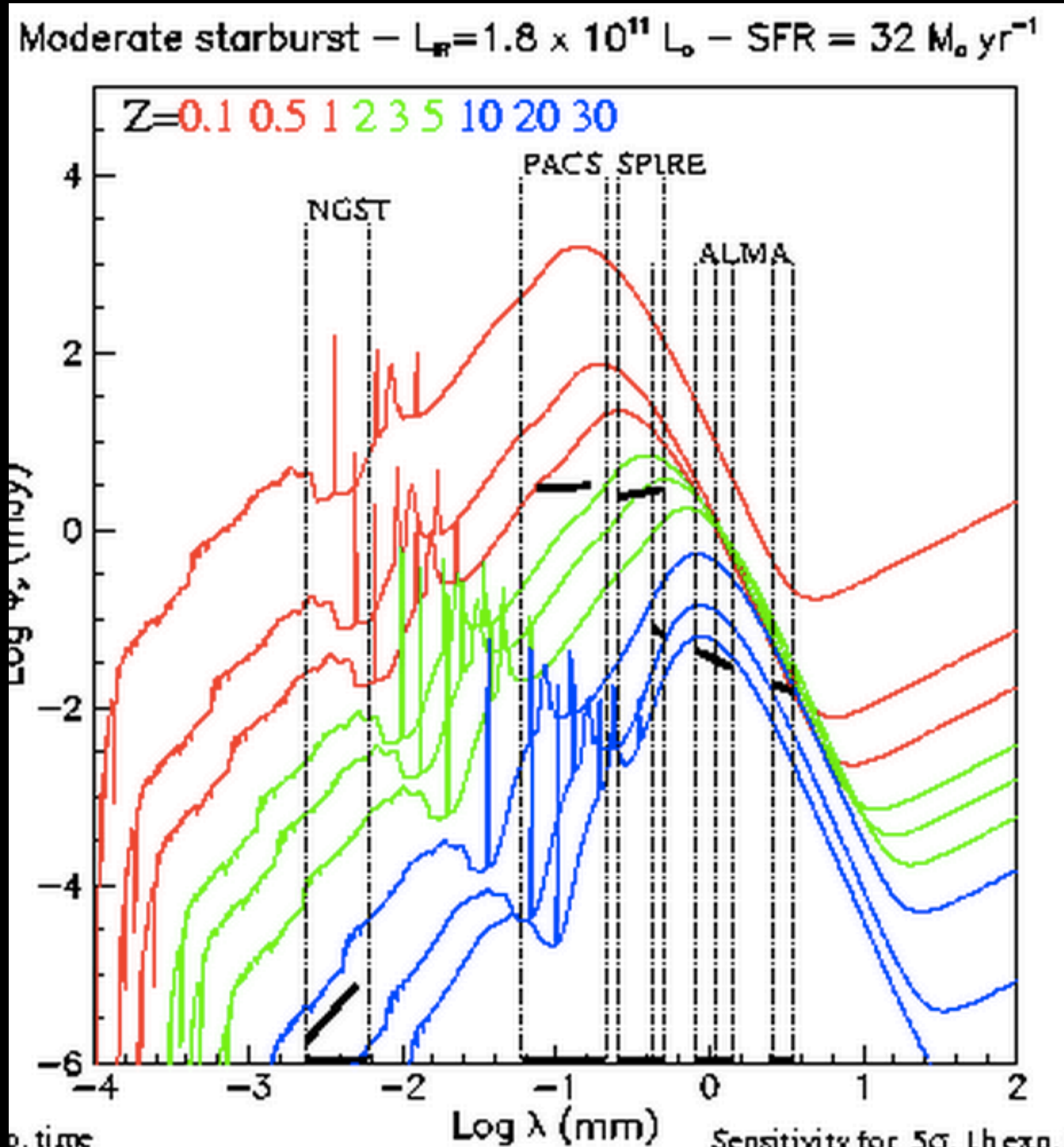




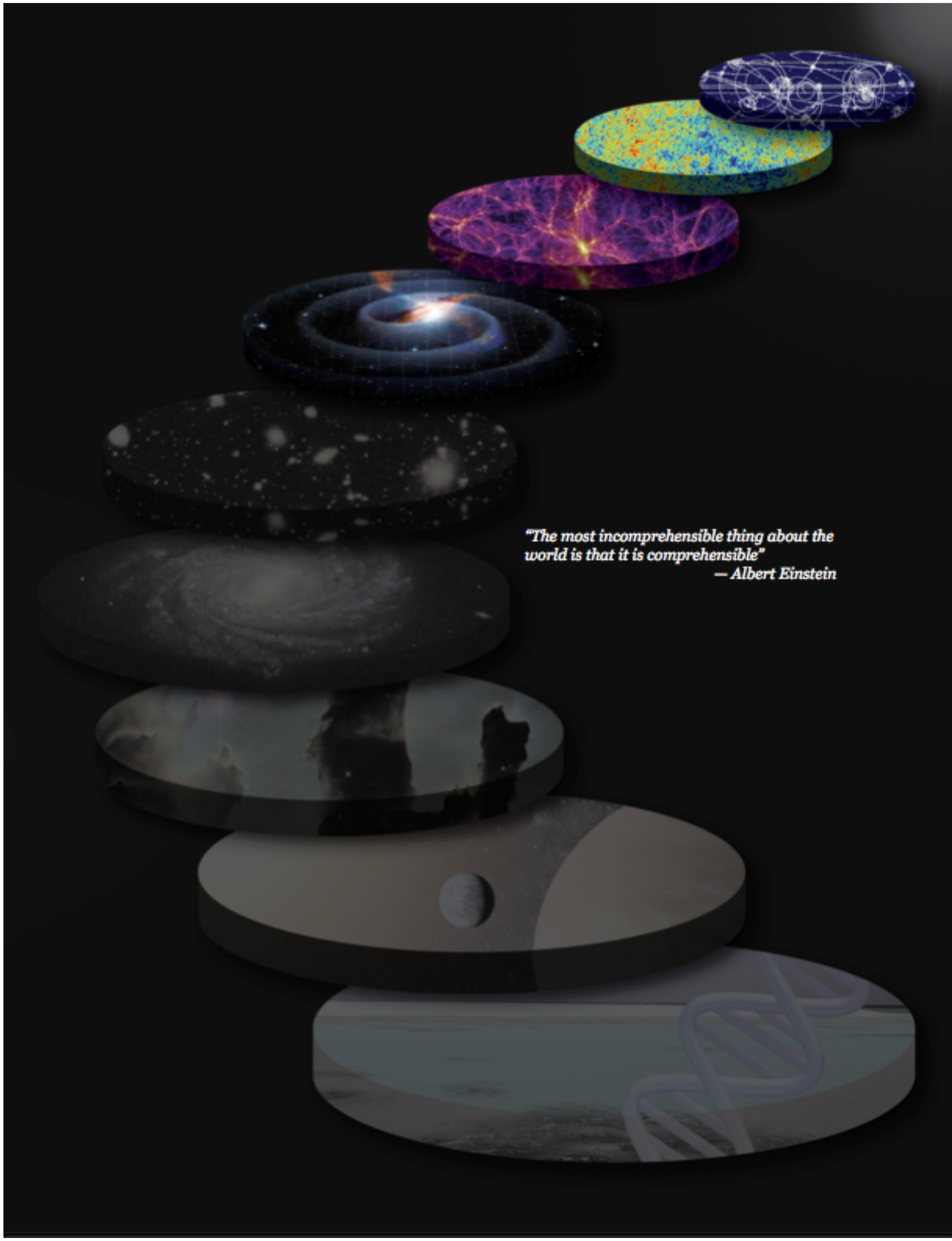
Milky Way and other Galaxies

Far IR Surveyor
needed to map spatially resolved complete SEDs in galaxies at z < 5 and may be even to z~10

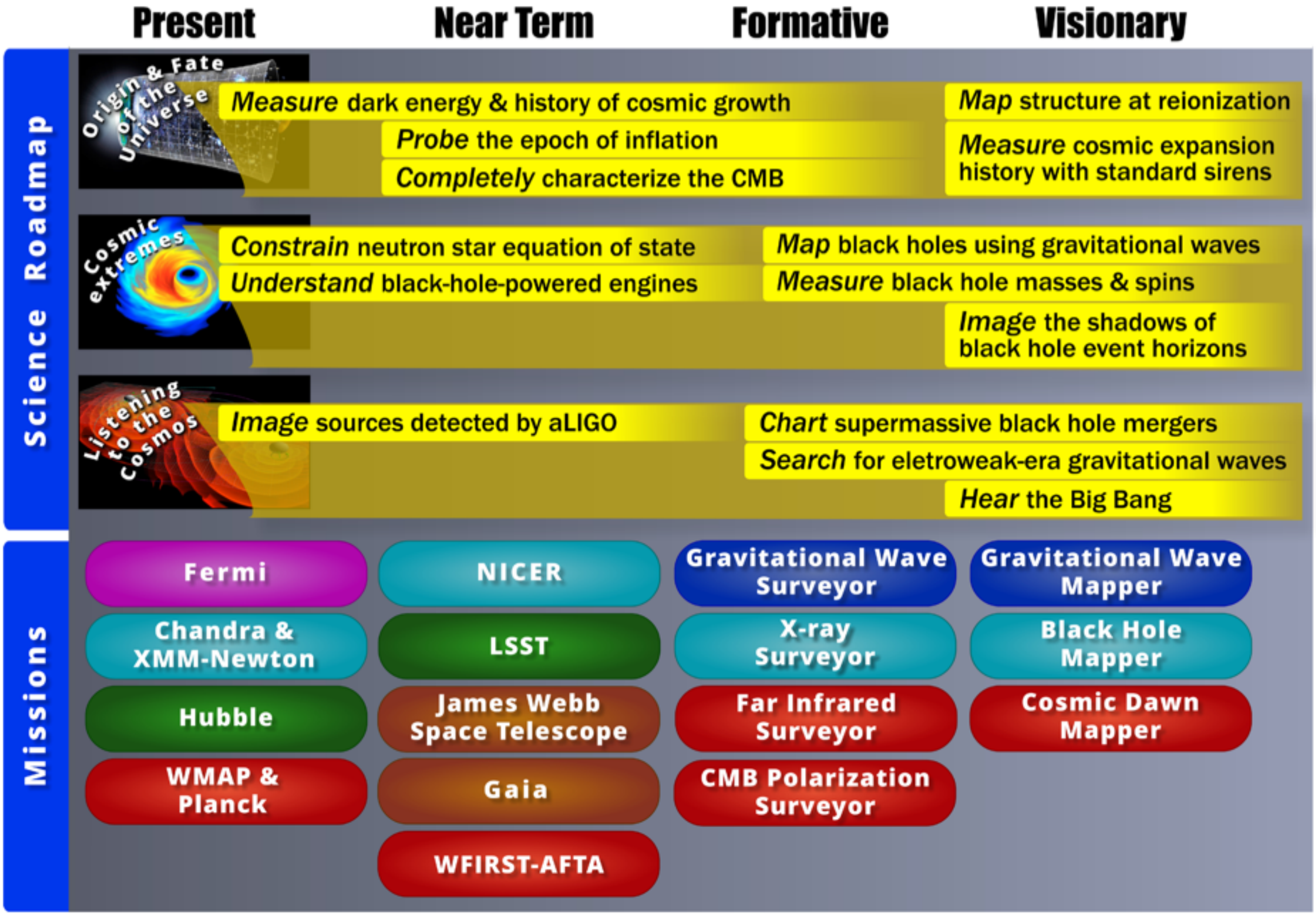
At z < 3, needed to trace fine structure emission atomic and water lines!



How does our Universe work?



Part 3: How Does the Universe Work?



First Light & EOR

A star cluster of the first generation may be detectable with JWST

A supernova explosion of early stars may be seen with WFIRST-AFTA

HI to EoR may be measured with SKA.

A large **LUVOIR** + **FIR Surveyor** may be needed if the first stars are more enshrouded than expected

Near Term Surveyors

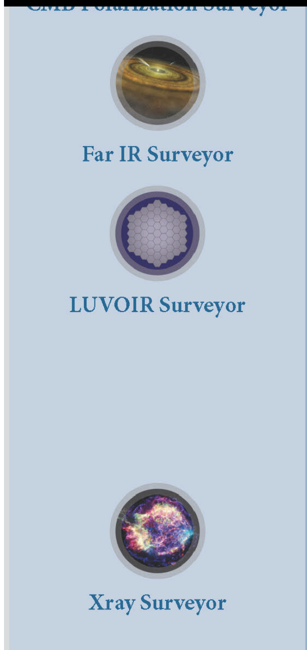
Far-IR Surveyor:

- Large gains to be achieved by actively cooled large dish (super-Herschel).
- Large aperture + high res spec and ultimately interferometry to get sub-arcsec FIR images.
- Low risk / platform for other interferometry missions

Tech needs:

- Segmented large single-aperture (10-20m) FIR telescopes
- Sub-Kelvin focal-plane coolers
- Space-qualified 4 K mechanical coolers
- Detector readout electronics
- Wide-field or multi-beam spectrometers

Near Term Surveyors



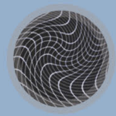
LUVOIR Surveyor:

- 8-16m for large collecting area and high resolution.
- 16m would give a diffraction limit of 8 mas – with coronograph can get Earth-like planets at 3μm to 10pc.
- Full wavelength coverage from 10microns to 91nm strongly constrained by technological constraints.

Tech needs

- Segmented technology development
- Robotic assembly
- Wavefront accuracy and stability
- High-reflectivity coating
- Large format high-sensitivity detectors from IR to UV
- Starlight suppression systems

Visionary



Gravitational Wave Mapper

Cosmic Dawn Mapper

ExoEarth Mapper

Black Hole Mapper

Visionary Era Mappers

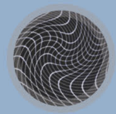
Gravitational Wave Mapper: Multi-detector arrays for imaging science to locate galaxies and counterparts where GW are emanating

Cosmic Dawn Mapper: 2-20m signals to study very high redshift 20cm line – array of thousands of radio antennas on the far side of the moon – goal to make 3D map of neutral gas from EoR to deep into the dark ages.

Exo-Earth Mapper: Large optical-near IR space based interferometer. >370 km separation, collecting area of 500 m^2, R~100 spectroscopy.

Black Hole Mapper: Xray interferometer with (sub)microarcsec resolution to image black hole event horizon. Space array of optics kilometer in diameter with focal plane detectors 1000s of km farther away.

Visionary



Gravitational Wave Mapper

Cosmic Dawn Mapper

ExoEarth Mapper

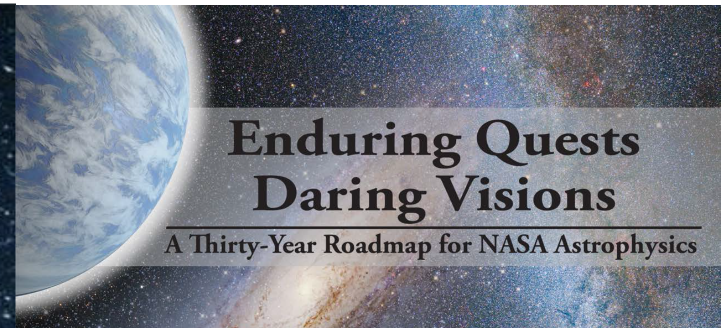
Black Hole Mapper

Far IR Mission

"As for large single-aperture telescopes, the technical requirements for interferometry in the FIR are not as demanding as for shorter wavelength bands, so FIR interferometry may again be a logical starting point that provides a useful training ground while delivering crucial science. "

- *Enduring Quests, Daring Visions, NASA 30 Yr. Roadmap*

- Please see the poster by Jim Condon (NRAO) entitled, "The Future of Far Infrared Astrophysics: Complementarity between Space Missions and Ground Based Observatories"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A Thirty-Year Roadmap for NASA Astrophysics